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METEOROLOGICAL RESEARCH COMMITTEE

An experimental pulsed-light cloud-base meter

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CONTENTS:

Summary

1. Introduction

2. Details of present experimental model
   - 2.1. System and layout
   - 2.2. Optical alignment
   - 2.3. Transmitter, receiver and display unit

3. Performance
   - 3.1. General
   - 3.2. Maximum range
   - 3.3. Minimum range
   - 3.4. Operation in precipitation

4. Recommendations for improvements

5. Conclusions

Appendix 1. Some aspects of transmission and reflection theory applicable to the pulsed-light problem

Appendix 2. Summary of Northolt trials reports

Diagrams: fig. 1 and 2

Photographs: Instrument fig. 3-5
Clouds etc. fig. 6-18

Summary

In 1950 the Meteorological Office obtained an experimental cloud-base meter from the Telecommunications Research Establishment. Trials proved unsatisfactory until a 25 ft. separation of transmitter and receiver units was adopted. The report covers the trials and modifications carried out by the Meteorological Office. Electronic and optical features of the instrument are discussed, together with the permanent outdoor housing system evolved. Performance details over the range surface to 15,000 ft. are given, including operation in haze and precipitation. Limitations of the present instrument are discussed and improvements suggested. A selection of photographs of the display covers a wide variety of echoes from cloud, fog, haze and precipitation.

Appendix 1 deals theoretically with the reflection and transmission of light by cloud and fog, and explains the low level working of the instrument.

Appendix 2 covers the two operational trial periods at Northolt and stresses the advantage of the pulsed-light meter over present observing aids.

1. INTRODUCTION

Development work on a cloud-base meter using the pulsed-light technique was carried out at the Telecommunications Research Establishment during the period 1945-49.(1) After the disappointing performance of two prototype models, a final model (2), employing earlier design techniques, was constructed and delivered to the Instruments Division of the Meteorological Office in 1950. After familiarisation trials in 1950, during which period certain minor modifications were made, the equipment was given a routine trial at Northolt aerodrome. The trial report emphasised the limitations of the meter in the range 0-1000 ft. due to the blanking effect of a permanent atmospheric scatter pattern on the height display.

Proximity of the transmitter and receiver optical assemblies was considered responsible for this failure to measure low cloud heights. Separation of these assemblies did not at first produce any improvement, due to optical alignment errors. Eventually with a 25 ft. separation and correct optical alignment the atmospheric scatter pattern was eliminated and cloud heights became measurable from surface to about 15,000 ft.

Further trials at Northolt in 1954 have included extensive photography of the cathode-ray tube display for many cloud types, and indicate the usefulness of the equipment in its present form.

2. DETAILS OF PRESENT EXPERIMENTAL MODEL

2.1. System and layout

Light pulses of very short duration but of high peak power are produced by discharging a condenser across an air gap. They are beamed as narrowly as possible by a paraboloidal mirror with its optical axis vertical. The pulse repetition frequency can be varied from about 1 to 20 per sec. A small proportion of the emitted light energy is collected by a similarly aligned receiver mirror after diffuse reflection and scattering mainly by cloud droplets. This energy is focussed through a small aperture on to a rapid response photocell and the burst of current produced yields a voltage pulse which can be amplified and displayed on the range time-base of a cathode-ray tube.

Synchronised triggering of the light pulse and the range time-base enables the delay between emitted and received pulses to be measured. A range scale calibrated directly in feet expresses the delay as a cloud height. The commencement of the displayed cloud-echo indicates the cloud-base height.

In the original equipment the 20 in. diameter mirrors were arranged with optical centres 2 ft. apart on a heavy cast metal base-plate. Beneath this assembly was housed the remainder of the equipment, with the exception of the display unit, which was placed 15 ft. from the main assembly and so could be operated from an indoor position if necessary. At this stage the apparatus was fully exposed and could not be operated in precipitation.

For the initial trials at Northolt a small outbuilding was erected for the main assembly, a hinged opaque roof being withdrawn during observation periods.

There were originally three supporting arms associated with each mirror (2) in order to locate the transmitter spark gap assembly and the receiver photocell unit. The extreme rigidity thought necessary at the time of design, to give critical optical setting, has not been justified. One support only is now used with each mirror (fig. 5), thus increasing considerably the available working surface.

For the second trial period the transmitter and receiver were separated successively 12 ft. and 25 ft. on a horizontal base-line. Successful optical alignment was eventually achieved with the greater separation, but no further work has since been undertaken with other base-line distances. This separation required the removal and re-assembly of all the associated receiver components on a separate base-plate. A separate housing was provided for the new assembly and could be opened

/ to

to expose the mirror during observation periods. The display unit was now placed in the main assembly housing next to the transmitter mirror (fig. 4). Finally both housings were fitted with optical plate glass roofs set at a suitable run-off angle, and these could be covered with opaque shutters during non-observational periods. This enabled the equipment to be tested for the first time during periods of precipitation. This present layout of the meter is shown in fig. 3-5.

A cathode-ray tube camera, adapted to fit the display unit, could be rapidly interchanged for the normal vizor to obtain permanent records of a representative range of cloud echoes, and other phenomena. A small representative selection of the photographs obtained is shown in fig. 6-18.

2.2. Optical alignment

It was considered that extremely critical optical alignment would be necessary. With the compact assembly of both mirrors on a single base-plate a horizontal light path was used and focus and axis adjustments were made with respect to a point light source at 500 yd.

The next method proved somewhat easier, and consisted of placing a point light source in the aperture position of the receiver, and so viewing two light beams at night. (The transmitter beam is easily visible at night). This new method could also be used for the separated type of meter assembly, but proved unsatisfactory at Northolt due mainly to the high artificial light factor obtaining during the night period.

On the separated assembly, recourse to direct measurement, spirit levelling and plumb-line methods eventually proved a satisfactory method of obtaining vertical beaming for both mirror systems. This setting gave a range trace which contained no permanent atmospheric scatter pattern but was found to display good cloud echoes over a wide range of heights.

Finally the mirror carriages were orientated so that the receiver beam could be swept in the vertical plane passing through the two mirror centres, whilst a vertical plane at right angles to this could be swept by the transmitter beam. This considerably simplified the optimum optical alignment procedure.

2.3. Transmitter, receiver and display units

2.3.1. Transmitter

The transmitter spark requirements are essentially:

(1) The light should reach maximum intensity in a fraction of a microsecond, to give sufficient discrimination at low cloud heights.

(2) The duration of the light pulse must be kept short, in order to keep the ratio of peak to mean energy high for efficient working.

(3) The light produced should have high intrinsic brightness, and luminous efficiency, and should match the spectral response characteristics of the photocell detector.

The light pulse should also be beamed as narrowly as possible to give maximum intensity at the cloud base and hence maximum contrast with daylight illumination.

Requirements (1) to (3) are met by a high frequency open spark discharge almost critically damped. An 0.05 microfarad condenser with terminals connected to a spark gap assembly, such that the total loop inductance is a minimum, is used in the present equipment. Duration of each half cycle of discharge is:

$\frac{2\pi L}{\beta}$ where L = total inductance

$$\beta = \sqrt{\frac{4L}{C} - R^2}$$

and β is positive for oscillatory discharge

R = resistance of spark gap

C = capacity of condenser

For maximum intensity and almost critical damping β and R must be small.

For minimum half cycle period L must be small compared with β. L probably increases approximately proportionally with C so that β is little changed, and therefore increase of L will widen the pulse, which is undesirable. In the present spark gap unit:

C = 0.05 μ F, R = 2.5 ohms

and L = 0.11 μ H

giving a half cycle period of 0.43 μ sec. Power in the second half cycle expressed as a fraction of the power in the first half cycle is:

$$\frac{1}{18400}$$

Power in the first half cycle is 10 megawatts approximately and assuming a conversion efficiency of 2 lumens/watt this gives 2×10^7 lumens for the light intensity of the spark.

A trigger spark, produced between the inner rod and outer shell of the positive spark gap electrode, provides an ionisation burst which fires the main spark. The electrode structure is shown diagrammatically in fig. 1. The back edge of a 25 μ sec. multivibrator pulse fires a ringing circuit which produces almost all its power in the first half cycle and is effectively a single pulse with a peak voltage of five kilovolts and width of two microseconds. This is the pulse which produces the trigger spark. See A and B of fig. 2.

To minimise electrode erosion the solid negative electrode is tipped with tungsten and the hollow positive electrode has a tungsten-nickel alloy cap with a central rod of tungsten. The only appreciable wear is in the rod and cap. This is because the rod is only 1mm. diameter and the cap thickness must not exceed 1mm. in order to keep the trigger spark close to the main spark gap. The tungsten rod can be fed forward as it wears, and the caps are replaced approximately every 50 hr. of running time. The spark gap unit is supported above the transmitter mirror and adjusted to give the narrowest pulsed beam possible with a vertical axis.

2.3.2. Receiver

This is a resistance capacity coupled video frequency amplifier capable of undistorted amplification of the light pulse detected by a photocell. It is divided into two sections of which the first is mounted above the receiver mirror with the photocell. This gives sufficient pre-amplification for cathode follower low impedance coupling to the second section, and helps to minimise the mirror blanking effect. The maximum gain is about 80,000. This can be increased and manually controlled by a further video stage in the display unit. The photocell is of the vacuum type with a caesium-antimony cathode. It has a very rapid response characteristic and peak sensitivity at a wavelength of about 0.45 microns. The circular photocell aperture is 8 mm. in diameter and is placed horizontally with its centre at the focal point of the receiver mirror which is adjusted so that its optical axis is vertical. The focal lengths of transmitter and receiver mirrors are respectively $8\frac{5}{8}$ in. and 12 in.

2.3.3 Display unit

This produces a range trace on a 3 in. cathode-ray tube possessing a fast writing characteristic. Three time-bases are available with sweep times of 7, 20 and 40 μ sec. corresponding to height ranges 3,500, 10,000, and 20,000 ft. respectively.

The waveforms controlling the time-base triggering and positioning of cloud echoes on the trace are lettered C to H in fig. 2. The 25 μ sec. multivibrator pulse C is differentiated and inverted yielding a 5 μ sec. negative triggering pulse which fires a phantastron circuit. This circuit produces a variable width square wave F with leading edge time coincident with the primary pulse C. The back edge of F can be adjusted by fine and coarse manual controls to occur anywhere in the range 15 to 60 μ sec. after the leading edge. This back edge controls the triggering of the brightening waveform G and the time-base waveform H. The brightening waveform produces the necessary trace intensity for visual observation at the low recurrence frequencies (1 to 20 pulses per second) and fast time-base speeds concerned.

The back edge of waveform C is displayed on the range trace, and forms a step marker indicating the commencement of the trigger spark pulse B. At some definite time interval after this commencement the main spark fires. By deflecting a small fraction of the transmitter light pulse over a minimum path between transmitter and receiver, a correct zero cloud height position can be obtained relative to the displayed step marker (see fig. 6). This zero setting eliminates the errors due to the 25 ft. separation of transmitter and receiver, build-up time of trigger pulse and any delay in the emission of the main light pulse. The remaining absolute error of about 15 ft. due to the height of the small diffuse reflectors used to obtain the minimum light path, together with the height of the transmitter and receiver mirror assemblies, can be eliminated as a standard correction. This is not justified in the present equipment as 15 ft. only represents 0.015 μ sec. light time and the present stability is not better than 0.1 μ sec.

Height is measured on perspex scales mounted immediately in front of the cathode-ray tube face. These scales are ruled with respect to 500 ft. markers, supplied by a crystal controlled calibrator, and take account of any slight non-linearity in the time-base. Subsequent positioning of the zero error setting signal by the phantastron controls, ensures that range measurements obtained from the perspex scales are always correct. This would not be so if the whole time-base was moved laterally to produce such a positioning, unless it was perfectly linear, a condition very difficult to attain at the speeds involved. The fine phantastron control is calibrated directly in feet and facilitates rapid zero setting, i.e. the step marker can quickly be set on the scale zero and then moved back a distance equal to the zero setting error. This error is about 800 ft.

The mounting of the display unit next to the transmitter is convenient, since all the switches and variable controls are to hand. However, the noise of the transmitter spark is a little disturbing, but quite tolerable.

3. PERFORMANCE

3.1. General

The successful alignment of the meter with a separated assembly, has undoubtedly greatly enhanced its usefulness, by making possible the measurements of low cloud heights in the range excluded by the original assembly.

The calculated rise time of the electrical pulse producing the main spark is about 0.2 μ sec. The rise time of the light pulse is only about 1.2 μ sec. This broadening is undesirable and is mainly due to the finite build-up time of the light pulse and speed of response of the photocell. Further broadening in the receiver amplifier sections is very small. Stability of the back edges of waveforms C and F (fig. 2) and of the delay which represents the zero setting error, are the limiting factors governing the accuracy of range measurement. An average figure for this error in terms of cloud height is 100 ft.

3.2. Maximum range

This at present is about 15,000 ft. On one occasion only a persistent small echo was received from cloud at 18,000 ft. Position persistence is an important factor in considering maximum range, for small echoes can be detected down to and even below noise level, by discrimination between haphazard variation of noise amplitude at any given position on the range trace, and the persistence at a fixed position of the small cloud echo.

A greater maximum range could of course be obtained by certain changes which include: using better quality mirrors of larger diameter, and perhaps shorter focal length, together with an increased spark intensity.

3.3. Minimum range

This is limited only by the stability factors mentioned in 3.1. and the rapidity of leading edge build up of the cloud echo. It is clear from an examination of the photographs of low cloud and zero check echoes that the initial portion of the leading edge is very similar in both cases, and does not seem to be dependent on the nature of the cloud. From a study of the shape of the zero check echo, it is possible to fix a point which can be accepted as the commencement of the leading edge. By fixing a similar point on a surface fog echo, it was found to give zero range. However, when the same fog began to lift it was difficult to assess the height of the base until it had reached 200 ft. It is clear that by producing a more rapidly rising leading edge for the received light pulse, cloud height measurement over the range 0-600 ft. would be much improved. Above 600 ft. the present discrimination is reasonable.

3.4. Operation in precipitation

Operation during precipitation from cloud bases in the range 600-5,000 ft. has presented no difficulties. Experience outside this range is lacking at present. On one occasion of heavy precipitation a considerable "bump" was noted prior to the cloud echo leading edge. All precipitation, above a certain density, produces a lifting of the range trace before the commencement of the cloud echo. There is however no difficulty in defining the section of the displayed echo associated with the cloud base. Experience in snow is very limited, but echoes have been received. The main problem is the rapid clearing of housing roof windows for which some automatic sweeping mechanism would be required. All types of precipitation give rise to a certain degree of attenuation of the cloud echo, due to scattering by the particles concerned and effective destruction of the plane optical surface of the glass roof sections by the water or snow which reaches them. This results mainly in a reduction of maximum range performance.

4. RECOMMENDATIONS FOR IMPROVEMENTS

(1) A decrease in the width of the transmitter electrical pulse could probably shorten the rise time of the light pulse, and so give the desired increase in discrimination at low cloud heights. A narrower light pulse would also yield more cloud type and thickness information from the shape and width of the displayed echo. However, the finite time required for the build-up of the transmitter light pulse, and the response of the receiver photocell, may be the limiting factor preventing sharpening of the cloud echo leading edge. Nevertheless, if a spark gap condenser with lower self inductance than the present one becomes available, it would indicate whether the probable limiting factors were indeed real ones. Reduction in the condenser capacity should also be favourable, but the working voltage may have to be increased to maintain the same peak intensity in the light pulse.

(2) Provision should be made for rapid zero range error checking. Two small diffuse reflecting plane surfaces attached permanently to the mirror assemblies, and presenting only a small blanking effect would suffice. One could be permanently orientated correctly, and the other when necessary, in order to reflect fractional transmitter pulse energy over a minimum path into the receiver.

(3) A simple optical device to indicate when cloud is within the field of view of the meter should be available near the display unit.

(4) A single phantastron display shift control with a full range of 1000 ft. calibrated at 50 ft. intervals could replace the two existing controls.

(5) An iris mechanism fitted at the receiver aperture would enable optimum conditions for maximum signal to noise ratio to be attained.

(6) Better matching of pulse handling feeders would help in preserving pulse edges.

(7) Thermal delay switching, associated with a preset main spark voltage, could eliminate three switching operations. Push-button control of main spark firing could be available at the display unit.

(8) Many of the manual controls now available on the experimental model could be replaced by preset controls. (7) and (8) would result in the present meter being put into operation by two switches and one push-button. A single manual control would then fix zero range before a reading.

5. CONCLUSIONS

The present experimental cloud-base meter has given sufficient evidence to indicate that the pulsed-light principle will give satisfactory height data. The only important limitation is that the cloud must be directly above the meter. The range covered is from surface to middle medium cloud. This range can be extended upwards by increasing and concentrating the spark pulse energy. To cover large cloud height ranges it would probably be necessary to have two or more transmitter units of different power outputs. As the optical system need not possess the critical rigidity once considered essential, it should be possible to design a mobile equipment capable of alignment in a period of not more than one hour. In its present form an operator is required to switch on and take readings from the display unit. Automatic strobing of the cloud echo might now be possible as the permanent scatter pattern has been removed from the display. This would in turn make distant recording feasible. Alternatively it would be possible to have the display unit and all switch controls within the forecasting or other appropriate room, with the transmitter and receiver situated in the open, each unit not more than about 30 ft. from the display. It is interesting to note that the present type of transmitter and receiver could be used on a fixed base-line to give heights by altitude-angle determination as with the modulated cloud searchlight.

APPENDIX I

SOME ASPECTS OF TRANSMISSION AND REFLECTION THEORY APPLICABLE TO THE PULSED-LIGHT PROBLEM

The theoretical reasons for choosing radiation in the visible light region are explained in a T.R.E. Report (1) but two further points concerning the transmission, reflection, and absorption by water droplets at visible light frequencies are worthy of mention.

The diffuse reflection of short wave radiation by clouds or fog is practically constant for the wavelength range 0.1 to 1.0 micron (μ) (4) and the greater part of all the energy in the pulsed light spark is concentrated within this band. The percentage of the incident short wave radiation reflected from a cloud-base is dependent on cloud droplet size, liquid water content, and cloud thickness. In the T.R.E. report (1) reflection of 10% was assumed, but from theoretical data prepared by Hewson (3) it is seen that this figure can vary from about 1 to 95%. Hewson was considering solar radiation, but as its spectral distribution of energy is reasonably similar to that given by the transmitter spark, his data is equally applicable.

For a cloud 200 m. thick of medium density 1.0 gm./m.^{3} and drop radius 5 μ, the reflection is about 80%. Hewson gives a figure of 20 μ for typical fog droplets and shows that about 85% of incident light would be transmitted and emerge from the top of a fog 200m. thick of density 0.1 gm./m.^{3} whilst 38% would get through if the density were 1.0 gm/m.^{3}. This explains why two cloud echoes are possible from a single emitted light pulse. If penetration of the cloud or fog can be assumed to be complete, then the resulting effective widening of the displayed echo can be expected to yield cloud or fog thickness information.

The diffuse penetration of cloud by light must give rise to halation of the spark image at the cloud-base. The effective diameter of the image will depend on the nature of the cloud as indicated by the transmission and reflection data given above. Even in very thick cloud this halation will be appreciable, e.g. Hewson gives a transmission figure of 24% after 20 m. penetration of cloud of water content 5.0 gm./m.^{3} with drop radius 5 μ. It is this property which accounts for the operation of the meter at low cloud heights. Below about 700 ft. with a 25 ft. separation between transmitter and receiver, there is no intersection of the transmitter beam and receiver acceptance zone even after making allowance for the divergence due to the finite size of the spark and receiver aperture. It is also this effect which must account for the less critical alignment required for the optical system than was at first thought necessary.

Beam divergence is important when maximum range is considered. The acceptance zone of the receiver should be as narrow as possible, in order to collect minimum permanent light factor (i.e. day or night natural illumination) and so keep the receiver noise at a minimum level. This suggests a spark approaching point source dimensions in order to concentrate the transmitter beam and thus make possible a reduction of the receiver aperture. A compromise must be made in order to maintain sufficient energy in the spark. As small spark gap working implies lower voltages, a much larger capacity would be required in order to maintain the same energy, and the loop inductance in the spark gap circuit would have to be reduced to keep the pulse width narrow, and so maintain a satisfactory peak pulse power. Latest condenser manufacturing techniques together with new dielectric materials may make this improvement a possibility.

APPENDIX 2

SUMMARY OF NORTHOLT TRIALS REPORTS

Phase 1 trial was carried out with the compact version of the meter and Phase 2 with the present separated assembly. The summary of Phase 2 trial is treated in detail.

Phase 1 covered a period July 1951 to January 1952 and the report was prepared by Mr. G.A. Corby. During a period of routine comparison observations, made at standard observing times, no readings were obtainable on slightly more than half the occasions, mainly due to inability to operate in fog and precipitation, the serious masking effect of the permanent low level scatter pattern and absence of cloud directly above the meter. The serviceability of the equipment was of a high standard and extreme heights recorded were 9,000ft. and 500ft. Difficulties were experienced in reading the display accurately, and the controls and switches were considered to be too complex.

Phase 2 covered a period March to October 1954 and the report was prepared by Mr. G. Needham. Certain performance details obtained during the trial period, which have been included in the main report, have been omitted from this summary.

1. INVESTIGATION

The main aims of this trial were:

(1) investigation of very low cloud and fog echoes which was found impracticable during Phase 1.

(2) investigation of cloud echoes during precipitation.

(3) photographic recording of cloud echoes to facilitate investigations of echo characteristics under different weather conditions and for different cloud types.

(4) collection of further display data to serve as a check on or to develop further appropriate sections of Phase 1 work.

(5) a re-assessment of the operational usefulness of the apparatus following the modifications carried out.

About 500 observations were logged and over 350 photographs taken during the period. The observations were analysed and compared with official observations taken about a mile away. The comparisons were not considered a satisfactory basis for the assessment of height accuracy because of the time distance separation involved.

2. RESULTS

2.1. Accuracy

Absolute height accuracy has not yet been assessed. It is considered that only very accurate altimeter information from an aircraft operating directly above the meter would be satisfactory, in the absence of a recognised standard cloud height meter. Reading errors are assessed at 100ft. on the 2,500ft. time-base, 200ft. on the 10,000ft. time-base, and 300ft. on the 20,000ft. time-base. These inaccuracies are due to the slight instability of the cathode-ray tube trace, smallness of the cathode-ray tube, and coarseness of height scales.

2.2. Range

The effective range can be said to be 0 - 9,000ft. with a good chance of receiving some echoes from higher medium levels, particularly from altocumulus. The chances of obtaining a return of sizeable amplitude from thin medium cloud are remote.

2.3. Scatter from intervening medium

In smoke haze, "bumps" on the display trace are sometimes pronounced, particularly at close ranges. A tendency has been noted for these "bumps" to coincide roughly with the estimated level of low inversions. With cloud above thick haze, a clearly defined echo is still received and height measurement presents no difficulties.

2.4. Multi-layer cloud

Part of the transmitted beam has often penetrated through thin parts of, or gaps in, the lower cloud layer, to higher layer(s). On one occasion three echoes were picked up on a single trace. On several occasions there were two echoes but more frequently echoes from different levels appear singly on any given range trace.

2.5. Interpretation of cloud echoes

There is a general feeling that echoes with the most definite commencement to their leading edge, are associated with cloud of high density, such as cumulus and stratocumulus. The width of the echo is probably a function of depth of penetration. Fairly sharp echoes of large amplitude and narrow width are usually found with cumulus and stratocumulus type clouds. Variations in the height of a cloud with a ragged or undulating base is easily recognised on the display trace. When observing individual clouds (e.g. cumulus) echoes are sometimes obtained from the overhang and from patches of fractus cloud at levels above the real cloud base. On these occasions it is necessary to report the minimum return if the base of the cloud did in fact pass overhead.

3. USEFULNESS OF THE PRESENT PULSED-LIGHT METER

Reliability of operation, reasonably close limits of accuracy, and an effective range of 0 - 9,000ft. with a chance of receiving echoes from higher levels make the meter a very valuable observing aid. The pulsed-light method of cloud height determination has distinct advantages over all other methods at present used by the Meteorological Office. Naturally the pulsed-light reading cannot always be included in the official observation; the reported cloud height(s) are required to be representative of the local area, whereas the height(s) indicated by the meter relate only to the cloud directly overhead at the time; interesting pieces of cloud often by-pass the meter or take a considerable time in arriving overhead.

Increased observing accuracy is of importance to the forecaster. Significant information which the meter can provide includes the height of cloud base up to medium levels and the character of variation of low cloud base. Some observers' doubts regarding the character of the night sky can be removed by intelligent use of the meter display.

The usefulness of the meter has not yet been fully exploited owing to limitations in the existing equipment. Useful confirmation of the height accuracy would be obtained by the assistance of aircraft.

4. LIMITATIONS AND SUGGESTIONS FOR IMPROVEMENT OF THE PRESENT METER

An improvement in the signal to noise ratio might increase the information obtainable from the display. A higher cathode-ray tube resolving power is desirable, with a tube of say 9in. diameter. Higher positional stability of the range zero is required. The calibration scale requires further subdivision, which would be possible with a larger cathode-ray tube. Suggestions are:

divisions at 100ft. intervals on the 2,500 ft. time-base

divisions at 200 ft. intervals to 5,000 ft. and thereafter at 500ft. intervals on the 10,000 ft. time-base.

divisions at 1,000ft. on the 20,000 ft. time-base.

Although the range is limited to 9,000 ft. for consistent cloud echoes, this is more than adequate for operational use at aerodromes. The full range is however required for reporting and forecasting purposes. Any improvement in maximum range must not be at the expense of the precision of base measurements on low cloud.

The complexity of switching and manual control setting of the meter is considered too great. Some simplification is strongly urged.

It is recommended that the power supply of 80 volts at 1600 c/sec. be replaced by standard mains supply, 230 volts at 50 c/sec.

The noise of the main spark is somewhat disconcerting and sound proofing or removal from proximity with the display unit would be to advantage.

Automatic recording is desirable, particularly at busy aerodromes. Continuous recording would be a boon during spells of marginal weather. This involves strobe-locking and hence a difficulty in deciding at what signal level locking is to take place. The signal level should be high enough to prevent locking on a precipitation or haze scatter "bump". This would necessitate a correction to the base height corresponding to the distance up the echo leading edge at which locking takes place. Experience with an improved display would help in assessing the problem of automatic recording more thoroughly.

5. USEFULNESS OF THE PULSED-LIGHT METER IN MEETING THE OPERATIONAL REQUIREMENT FOR LANDING AND TAKE-OFF OF AIRCRAFT

As the measurement of slant visual range is still not possible, the immediate concern of Operators is the accurate reporting of cloud-base for assessing the landing critical height.

Runway visual range and visual range of obstacles in the exit path are the important factors for assessing safe take-off conditions. The cloud height should be representative of conditions along the glide-path. For the great majority of aerodromes the critical height will be 600 ft. or less.

Pulsed-light meter readings apply only to clouds directly overhead and, so to comply fully with the operational requirement, the meter must be situated on the approach path and, even so, cloud heights at more than one position on this path may be required. Different runways would require the installation of several sets, so that a mobile meter would be the only economical approach to the problem. Continuous operation of the meter in conditions of low cloud is very desirable.

The pulsed-light meter in its present form would not fit into this instrumentation pattern, but, if it could be made mobile and capable of continuously recording cloud heights when necessary, it would go far in helping to solve the operational problem.

To get the most out of the information displayed, operation by a meteorological observer, in addition to self recording, is recommended. It may be possible to obtain slant visual range with the meter, if the mirrors can be lowered to the appropriate angle, and their beams made to intersect over the whole length of the visibility path considered. This possibility should be investigated. Success will depend on true absorption being negligible, compared with reflection and transmission, and that the path concerned traverses a fairly homogeneous medium. Comparisons would have to be made with air to ground slant visibilities, to assess the change imposed by the different backgrounds.

Regardless of the difficulties in meeting the full operational requirement, the value of the pulsed-light meter as an observing aid has been proved, and this is in itself sufficient justification for the development of a production model. Increased reporting accuracy is a step in the right direction towards reduction in the number of aircraft accidents, and an improved economy of aircraft operation.

Acknowledgements are gratefully offered to Mr. G.A. Corby and Mr. G. Needham for the patience, enthusiasm and helpful criticism given during the respective trial periods of the meter at Northolt, and for preparing very useful reports on these trials.

Mr.R.K. Pilsbury is to be especially thanked for his patient work in obtaining the excellent photographic records of the meter display, covering all types of cloud within the range of the meter, fog, haze and zero error checks.

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Figure references of photographs.

Fig. 3. General view of cloud-base meter showing the transmitter and display housing on the right, and the receiver housing on the left.

Fig. 4. Transmitter and display unit housing. The transmitter chimney shield has been lifted to reveal the mirror and spark gap assembly.

Fig. 5. Receiver unit with housing removed.

Fig. 6. Zero check echo showing separation between step marker and commencement of echo (upper scale).

Fig. 7. Surface fog indicating zero height. (upper scale)

Fig. 8. Lifted fog at 200 ft.
Compare with fig. 6. Height obtained from the calibrated scale (upper) includes the zero error.

Fig. 9. Stratus at 500 ft. received through moderate rain. (lower scale)

Fig. 10. Fractostratus at 800 ft. (upper scale)

Fig. 11. Cumulonimbus at 2,100 ft. received through moderate shower showing effect of precipitation before main echo.

Fig. 12. Cumulus at 3,100 ft. (lower scale)

Fig. 13. Cumulus at 4,000 ft. with stratocumulus above at 5,600 ft. (lower scale)

Fig. 14. Stratocumulus at 4,500 ft. (lower scale)

Fig. 15. Altostratus-altocumulus at 6,700 ft. with evidence of second echo at 8,000 ft. (lower scale)

Fig. 16. Altocumulus at 9,600 ft. double trace. (lower scale)

Fig. 17. Altocumulus at 14,000 ft.

Fig. 18. Four separate traces showing effect of smoke haze on evening of November 5, 1954. No cloud overhead at time. (lower scale)

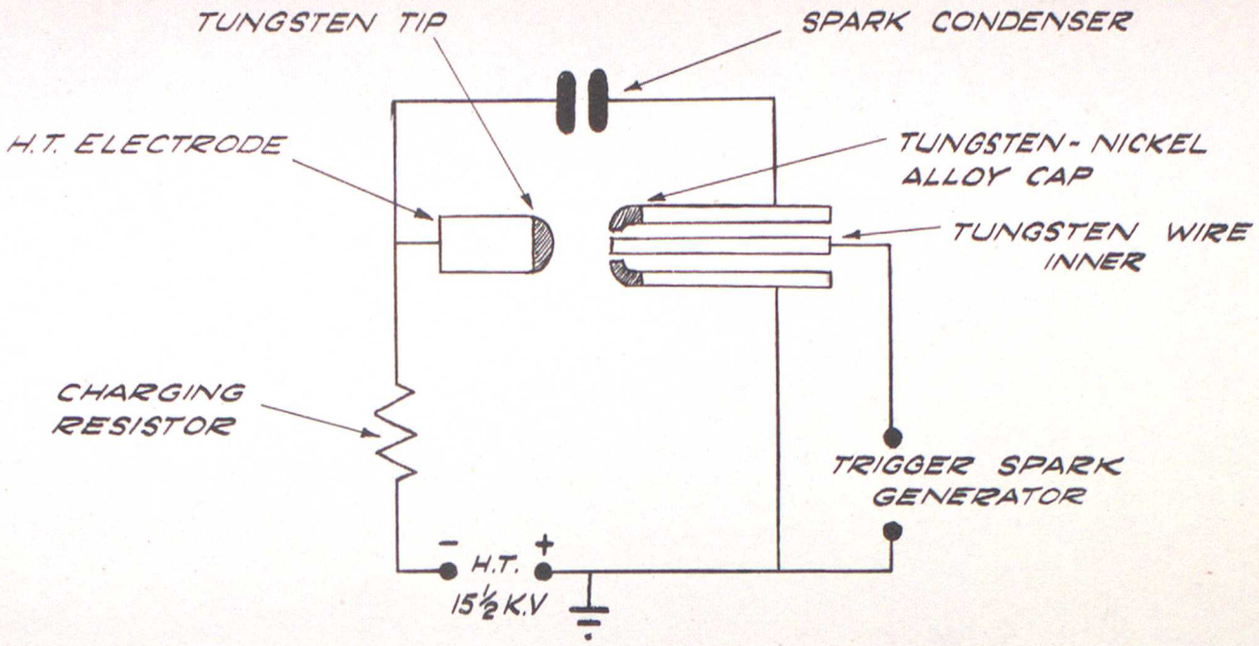

FIG. 1

BASIC ARRANGEMENT OF SPARK GAP CIRCUIT

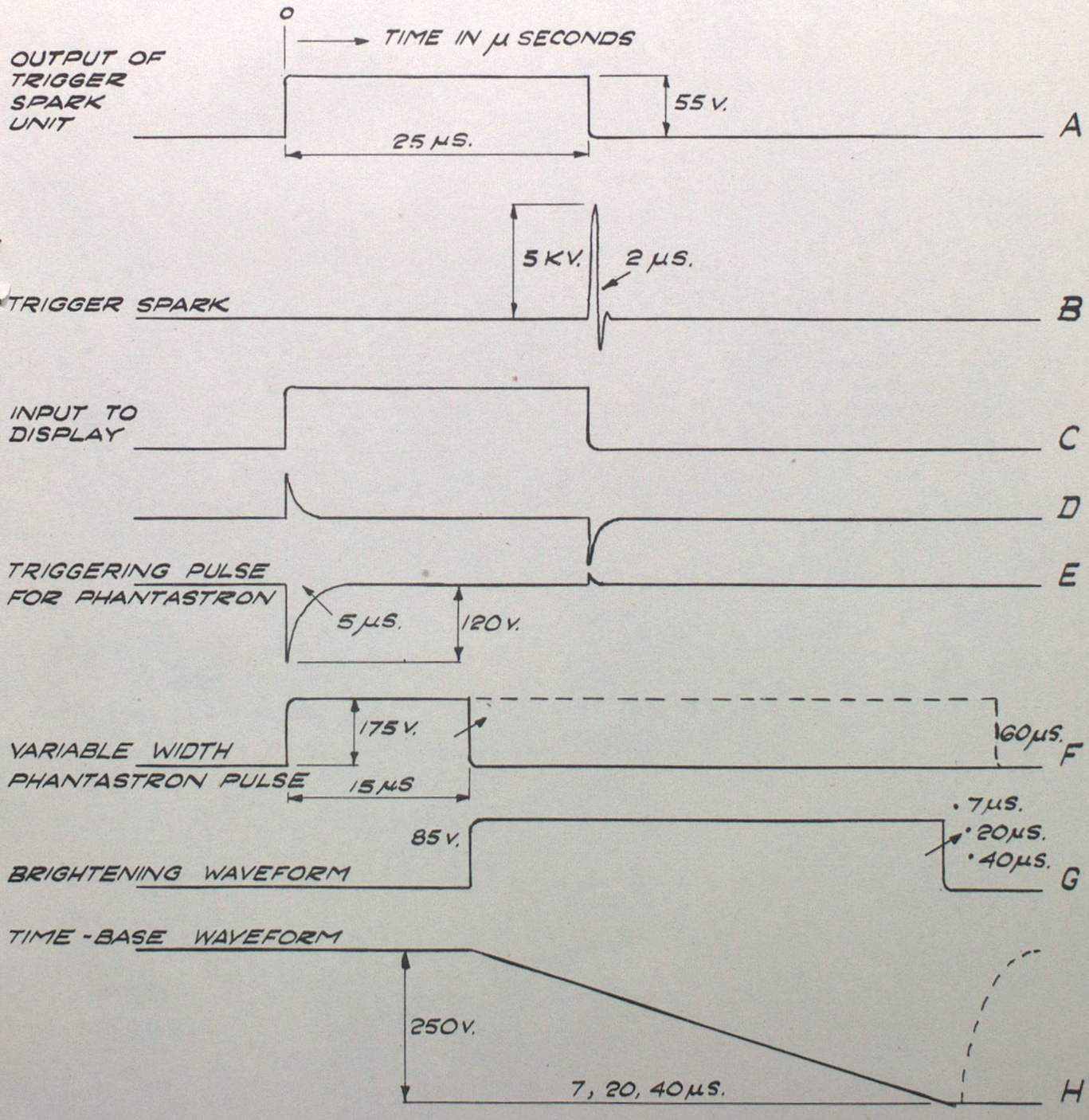

FIG. 2

DISPLAY UNIT WAVEFORMS

Fig. 3. General view of cloud-base meter.

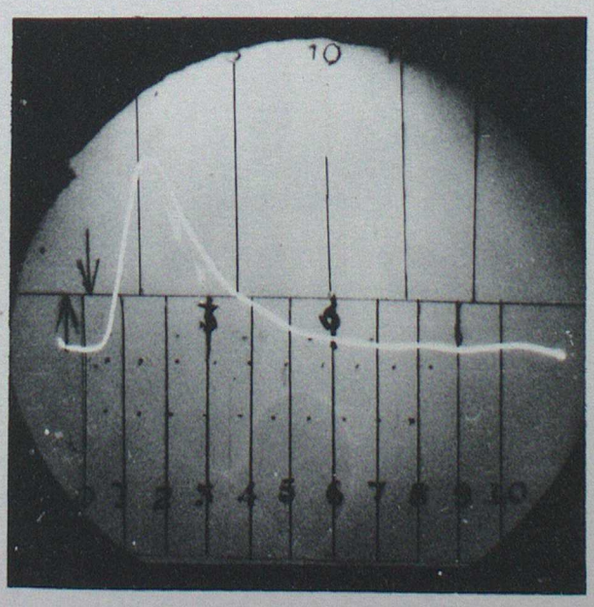

Fig. 9. Stratus at 500 ft.

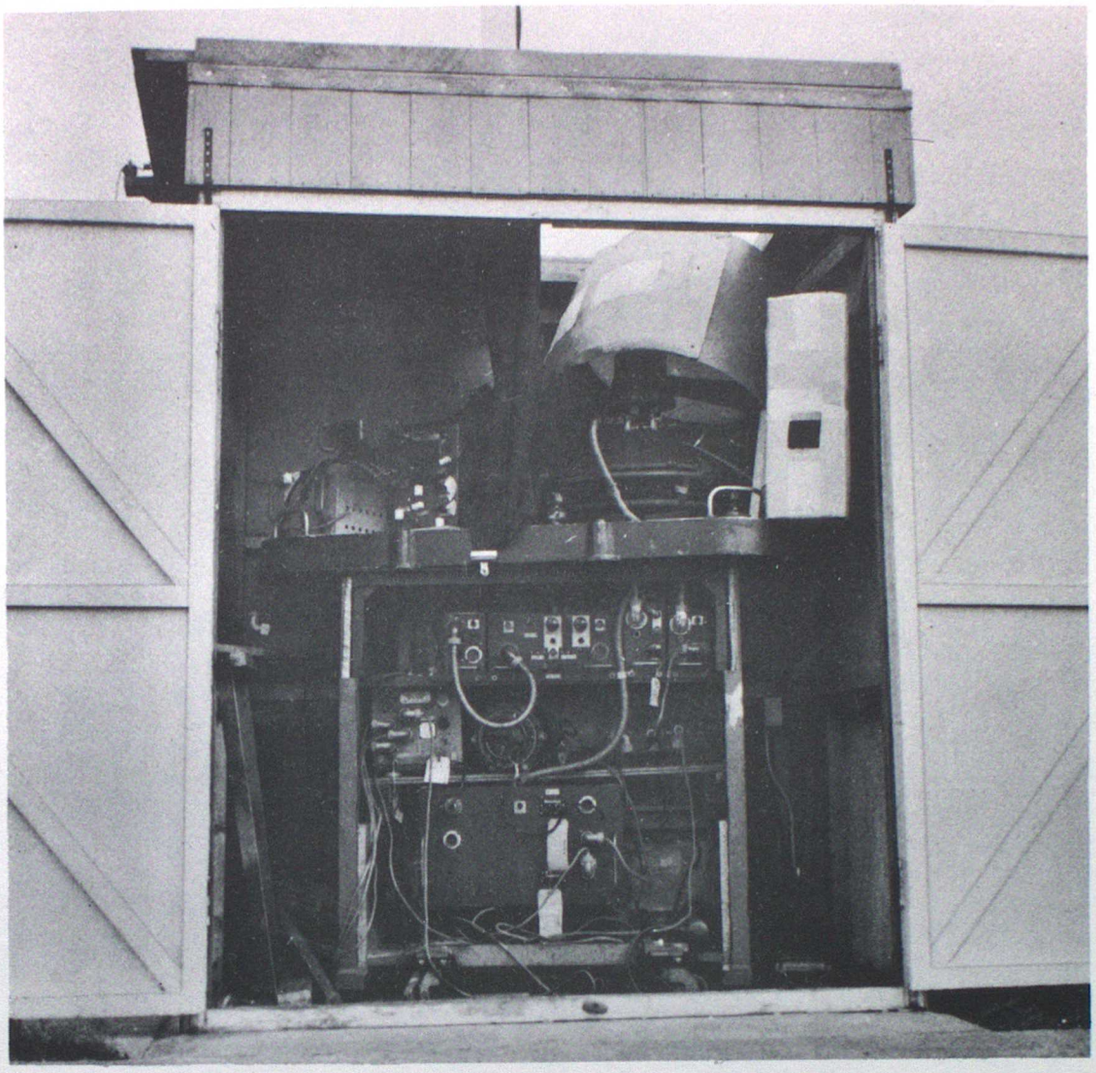

Fig. 4. Transmitter and display unit.

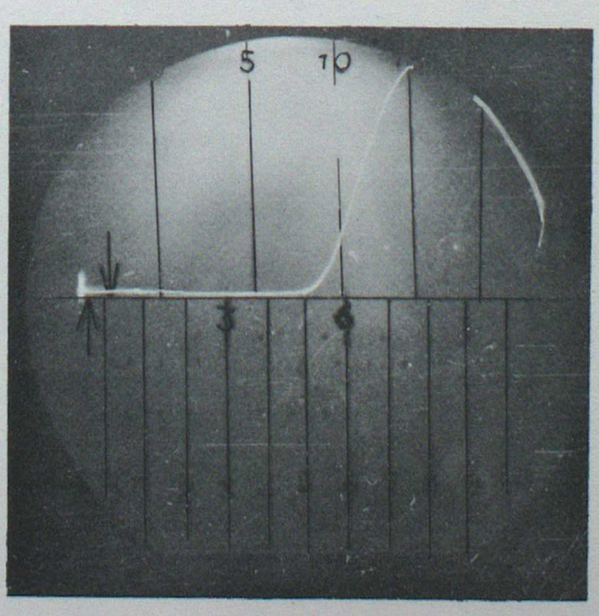

Fig. 10. Fractostratus at 800 ft.

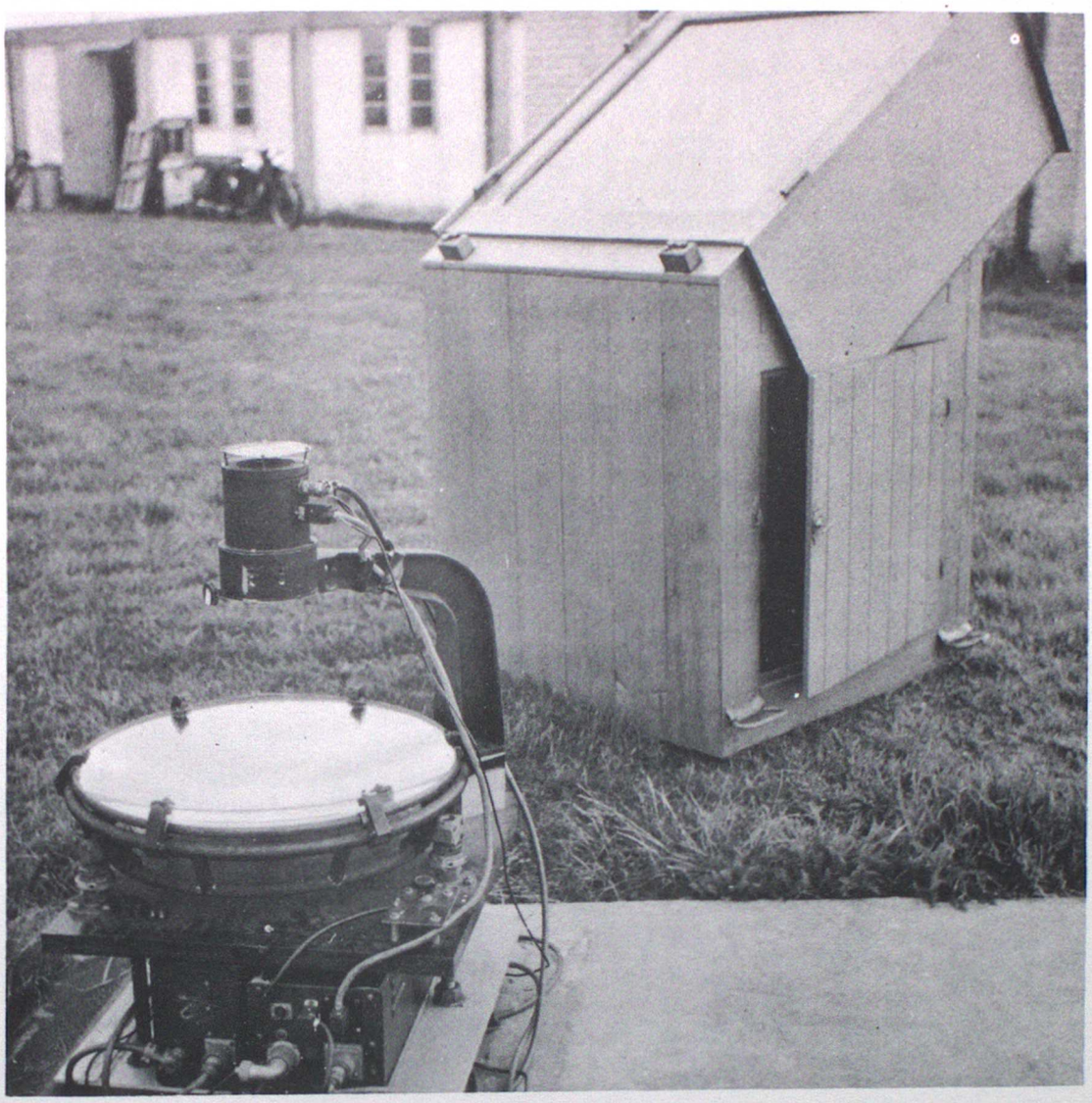

Fig. 5. Receiver unit.

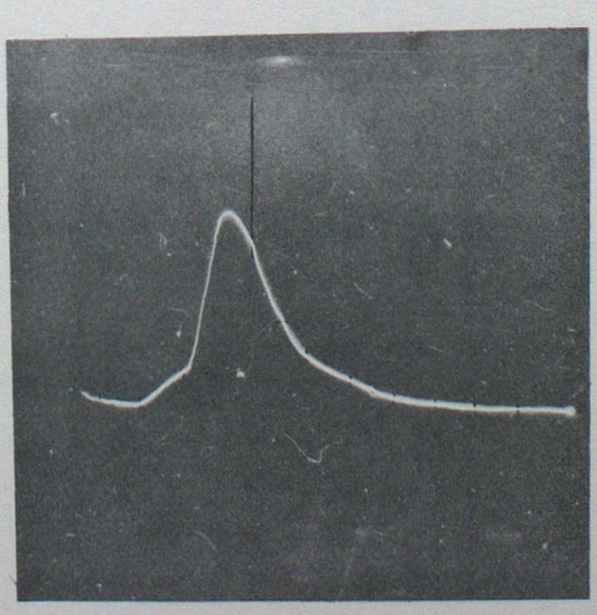

Fig. 11. Cumulonimbus at 2,100 ft.

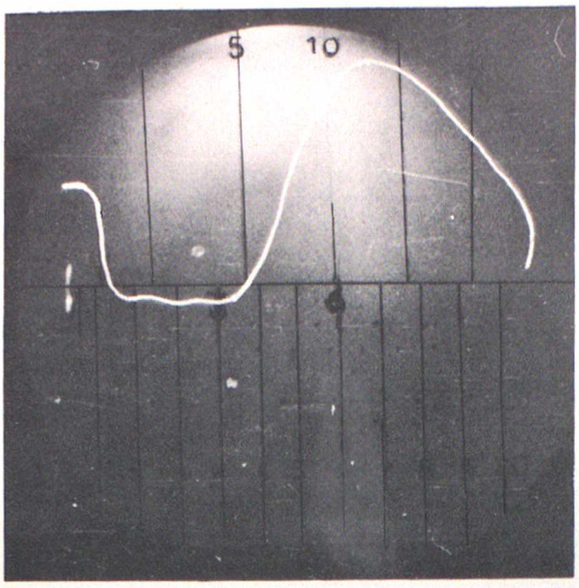

Fig. 6.
Zero check
echo.

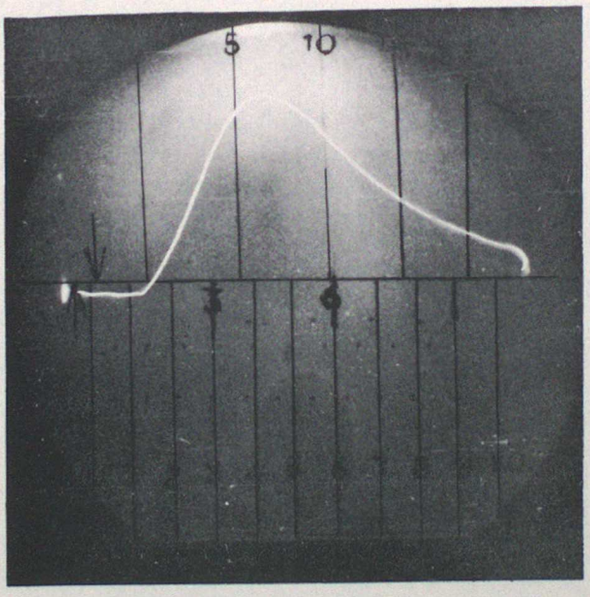

Fig. 7.
Fog

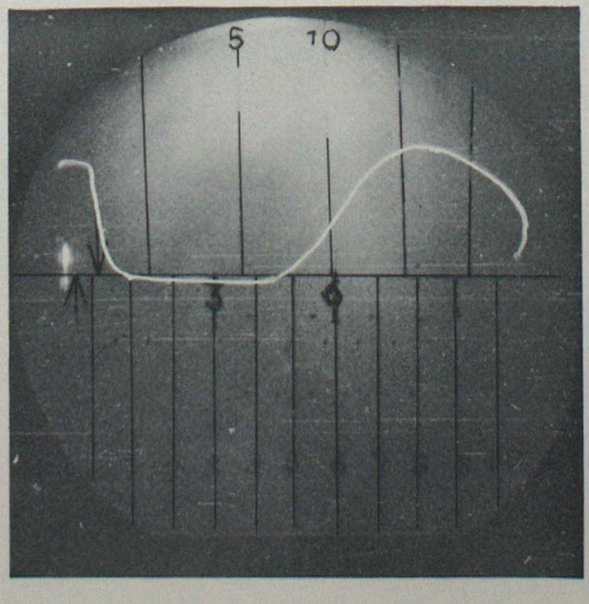

Fig. 8.
Lifted fog
at 200 ft.

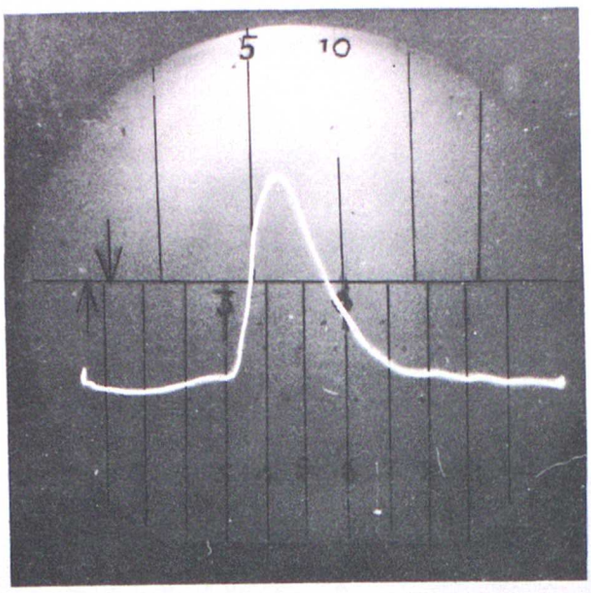

Fig. 12.
Cumulus at
3,100 ft.

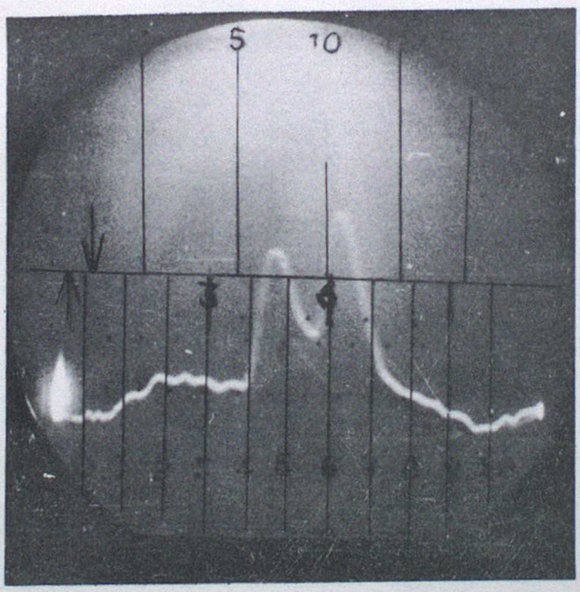

Fig. 13.
Cumulus at 4000 ft.
stratocumulus
at 5,600 ft.

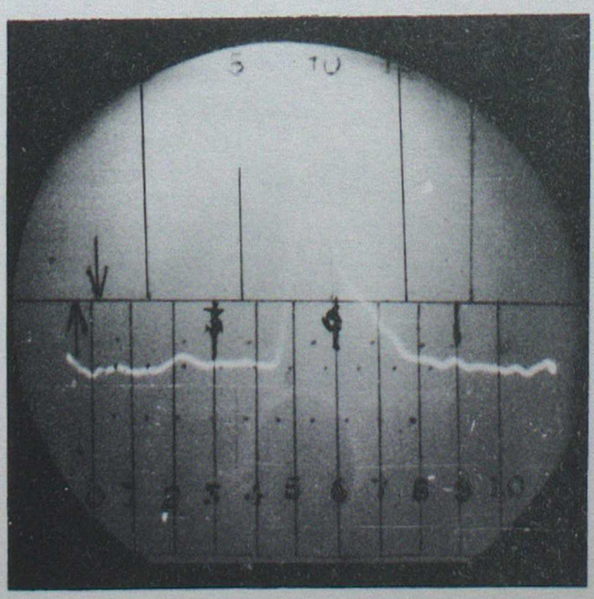

Fig. 14.
Stratocumulus
at 4,500 ft.

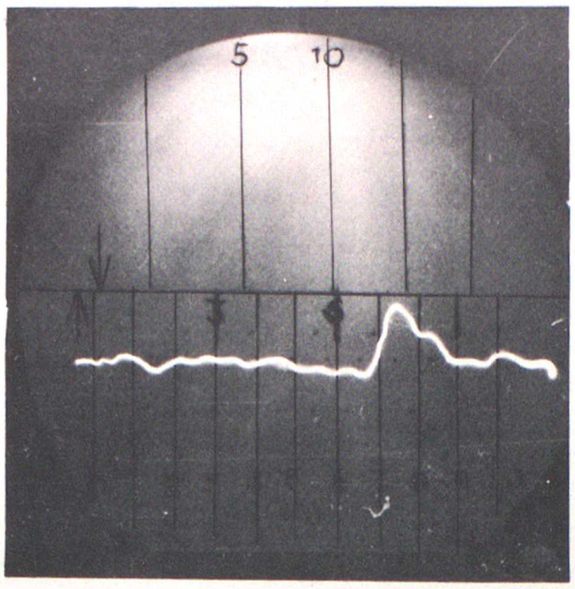

Fig. 15.
Altostratus
altocumulus
at 6,700 and 8,000 ft.

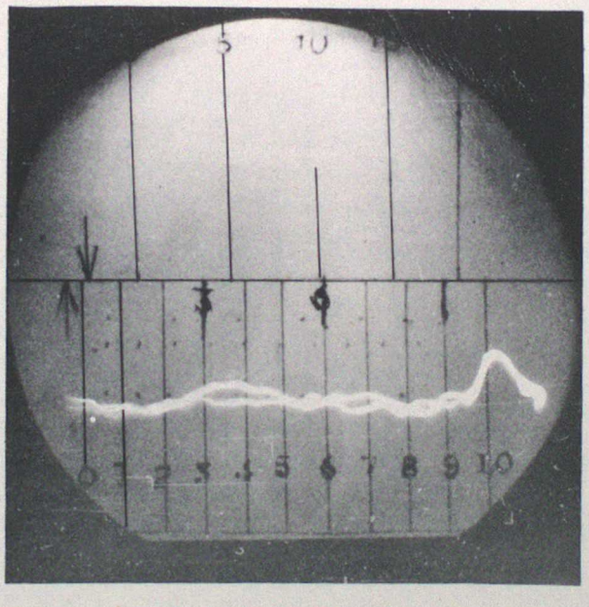

Fig. 16.
Altocumulus
at 9,600 ft.

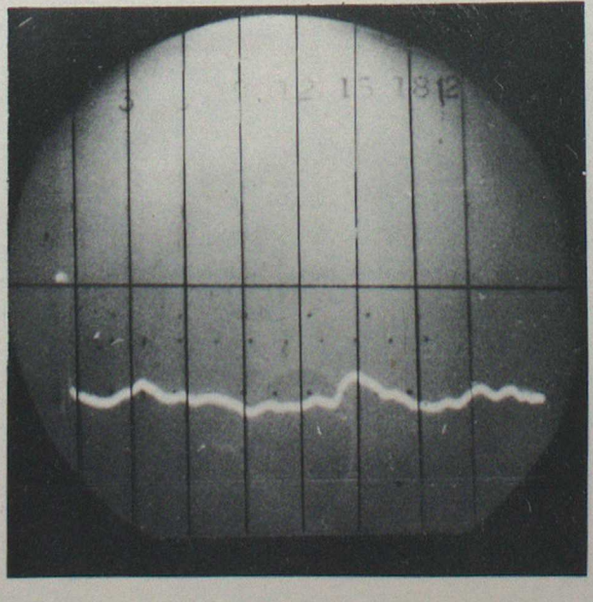

Fig. 17.
Altocumulus
at 14,000 ft.

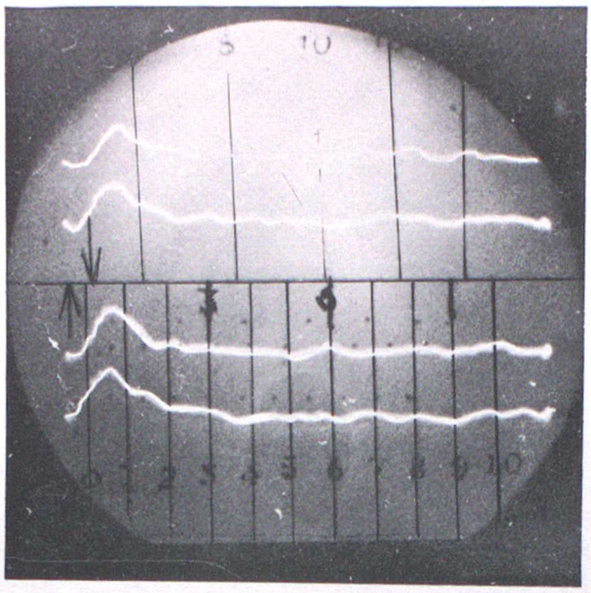

Fig. 18.
Smoke haze
(four traces)